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CHARACTERIZATION AND COMPOSITION ANALYSIS FOR INVESTIGATION OF BIOGAS YIELD FROM MUNICIPAL SOLID WASTE: A CASE STUDY IN THE UNIVERSITY OF BENIN, UGBOWO CAMPUS

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Abstract:
The main disposal method for municipal solid waste in Nigeria is open dumps. Generators of waste either burn their waste or dispose of it in the nearest open land, roadsides, or drains. It is unsustainable and leads to environmental, health, and aesthetic damage and depletion of natural and economic resources. A systematic study was conducted in the University of Benin, Ugbowo campus for quantification, determination of composition, and studying existing solid waste management practices and biogas potential from solid wastes. The total waste generated over a month is about 10,144.4kg. Based on this, the per capital waste generation rate is 0.33Kg/cap/day. Therefore, daily, 10.244tonnes of organic fraction of municipal solid waste is generated in the University of Benin. It will result in an expected 968.30m3 of biogas generated from the organic fraction of municipal solid waste of the University of Benin, Ugbowo metropolis per day. Considering the characteristics of waste generated in the University of Benin, Ugbowo campus, a systematic blend of management options in the waste management with biogas technology consideration as the best biowaste treatment method would be more suitable than the unsustainable collection and final dumping system that is presently practiced. Besides the biogas and generated renewable energy, the digested can serve biofertilizer, which can be used to cultivate crops.

Keywords: Solid Waste Management, Degradable Waste, Anaerobic Digestion, Biogas

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INTRODUCTION

Rapidly increasing populations, economic growth and affluence have contributed positively to the generation rate of Municipal Solid Waste (MSW), causing a major challenge to its management worldwide (Aguilar-Virgen *et al.*, 2010; Al-khatib *et al.*, 2010; Fakare *et al.*, 2012; Nabegu, 2010). MSW management problems are more prominent in the middle- and low-income countries due to wealth, fast-growing population and urbanization (Alam and Ahmade 2013; Damtew and Desta 2015; Tchobanoglous and Kreith ,2002: Bogner, abdelrafie, Diaz, Faaji, Gao, et al., 2007; Johnstone and Labonne, 204; Cohen, 2004). The increase in solid waste generated per capita in Africa has not been accompanied by a commensurate growth in the capacity and funding to manage it. It is reported that less than 30% of urban waste in developing countries is collected and disposed of appropriately. Improper and inefficient solid waste management leads to GHGs emissions, odors problems, and a high risk to public health. It has been predicted that the emission of GHGs from waste management in developing countries will increase exponentially (Friedrich and Trois, 2011).

Waste Management is a vital element of environmental protection. Its purpose is to provide hygienic, efficient and economic solid waste storage, collection, transportation, and treatment or disposal without polluting the atmosphere, soil or water system. The knowledge of the sources and types of waste in an area is required to design and operate appropriate solid waste management systems (Oyelola and Babatunde, 2008). A fundamental understanding of the sources and types of solid wastes is key in evaluating the composition and generation rates of MSW sources in a municipality.

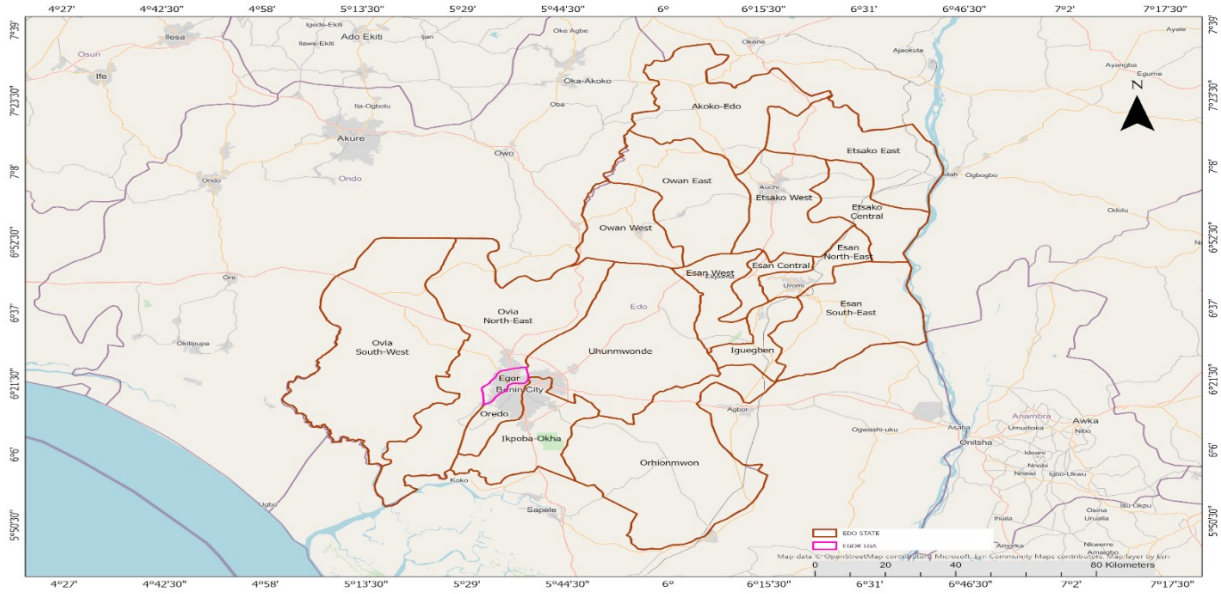
Cities in Nigeria, being among the fast-growing cities globally (Onibokun and Kumuyi, 1996), are faced with the problem of solid waste generation. By 2025 with a projected population of 233.5 million, Nigeria will generate an estimated 72.46 million tonnes of waste annually at a projected rate of 0.85 kg of waste/capita/day. It means that Nigeria's annual waste generation will almost equal its crude oil production, which currently stands at approximately 89.63 million tonnes per year. The main disposal method for municipal solid waste in Nigeria is open dumps. Generators of waste either burn their waste or dispose of it in the nearest open land, roadsides, or drains. These improper waste disposal practices may cause environmental, health, and aesthetic damage and depletion of natural and economic resources (Cao and Wang., 2017; Babayemi and K. Dauda., 2009; Adeniran Nubi, and Adelopo., 2017). On open dumping grounds, rodents spread disease-causing pathogens in the surrounding areas. Foul odors and air pollution are also a hazard to the surroundings. Apart from these, leachate seepage pollutes the waterways and other water resources used for human consumption.

Based on this backdrop, this study characterizes and quantifies municipal solid waste to determine its potential for commercial production of Biogas as a way of waste to energy. The University of Benin is considered in the present study as a sub(model)-a municipality in Edo state.

METHODS

The University is located in the Egor Local Government Area of Edo state. Major activities on campus focus on teaching, research and community services. Academic, administrative, residential and commercial spaces are provided in carrying out these functions. The majority of the area has permanent structures and complexes, which are often purposely built for a specific activity.

Figure 1. Map of Edo State



Source : Google Maps

Data was collected through primary and secondary resources. Primary data were collected through the preliminary survey, face-to-face interviews and questionnaire survey. Study of published and unpublished government agencies reports/records, private agency reports and literature reviews informed the secondary data. In addition, recognizant visits were made to randomly selected households to inform occupants about the survey work and to communicate the importance of the respondent participation and how the respondents will be involved. Also observed were the size and structure of building/units, building security and accessibility to temporary waste dumpsites or bins or storage. Within the university community, interviews were conducted that focused on the availability of disposal sites, regularity of collection of waste, problems and challenges of waste management in the communities and methods of managing the waste. Questionnaires were also administered during the study period to gather primary data.

A combined sample size of 1164 samples was collected for the duration at three(3) days intervals. Ninety-seven (97) sample sites were visited, above the minimum number of households of 50 per 500 households suggested by the EPA (1996). The sample size was above what was statistically needed to help limit the margin of error, and achieve better accuracy. A stratified systematic sampling method was employed at each of the three stratified zones to ensure appropriate representation in the entire population. 3-way sorting (food, fruit and others) of waste was done by respondents and sanitary officers. The sorted waste was first examined to ascertain if either rodents or scavengers had compromised the bags, then the content was examined to determine the composition of waste before weighing using a weighing balance, and the sampled bags were labeled for identification by waste managers. The bag with mixed content (others) was further sorted into various streams. Data on the mass of waste was collected from the field three times a week for four weeks. A sample of sorted waste (organic) was collected into sample bottles and taken to the laboratory to ascertain moisture content and for microbial analysis.

In a second phase of the study, obtainable biogas was determined from the organic fraction of the waste following the same equation adopted by Akhator *et al*. (2016). Total solid (TS) and volatile solids (VS) were used to calculate the obtainable amount of biogas. Kigozi *et al*. (2014) stated that on average, TS of OFMSW is about 27.14%, and the VS is about 94.90% of TS. USEPA, (2008) has established that the biogas production from OFMSW is around 367m3/kgVS. The above values were then applied in the basic theory equation below to produce biogas from the organic fraction of solid waste to determine the obtainable biogas from OFSW at the University of Benin.

Total biogas obtainable = Amount of food waste (t) × VS (%) × Biogas yield (m3 /t VS)

RESULT AND DISCUSSION

Although the waste management chain in the study area bears similar characteristics with the Benin metropolis, the environmental condition and attitude to waste disposal does not completely reflect the general Benin metropolis. There were sightings of dumpsters on strategic positions around the University; although there is room for improvement, the populace uses these waste bins to a good extent. Solid waste source segregation is not practiced by residents, commercial operators, staff and students of the University. Some form of waste sorting was also observed in the areas that employ sanitary workers like the student hostels, administrative blocks, library and all faculties. The cleaners sort and gather the plastic bottles separately. It is assumed that the plastic bottles were sorted to be sold for monetary gains. It is not regarded as source segregation because the sorting was observed at the temporary dumpsites at faculties and student hall of residents. However, even after sensitization,

the level of participation and efficiency of sorting continued to decline at the resident quarters. From observation of the attitude of the residents, they wanted monetary benefit to sort the waste. In the course of the study, some of them actually requested monetary benefits.

The data obtained through the administration of site-specific sampling and interviews were analyzed using tables, pie charts and percentages. The amount of waste types generated from representative samples in the study area over the study period is represented in table 1.

Table 1: Statistics of waste types generated for all levels, at Ugbowo campus Uniben

	Mean quantity in 12 days (kg)	SE	Variance	Range of waste quantity (kg)	Total waste (kg)	No of strata	ANOVA *P*-value
Fruits waste	29.4±28.3	16.34	801.1	55.5	1058.4	3	
Food waste	78.43±67.2	38.8	4515.3	132.9	2823.5	3	
Plastic	82.03±16.5	9.5	270.9	31.5	2953.5	3	
Paper	43.2±13.9	8.02	193.4	27.2	1559.6	3	0.018
Glass	5.92±4.47	2.58	20.0	8.7	213.3	3	
Metals	4.66±1.64	0.95	2.69	3.06	162.5	3	
Combustible	29.4±46.9	27.08	2200.9	81.5	1055.0	3	
Leaves	8.03±9.3	5.4	86.9	18.26	271.1	3	
Ceramics	1.32±2.28	1.32	5.22	3.9	47.5	3	

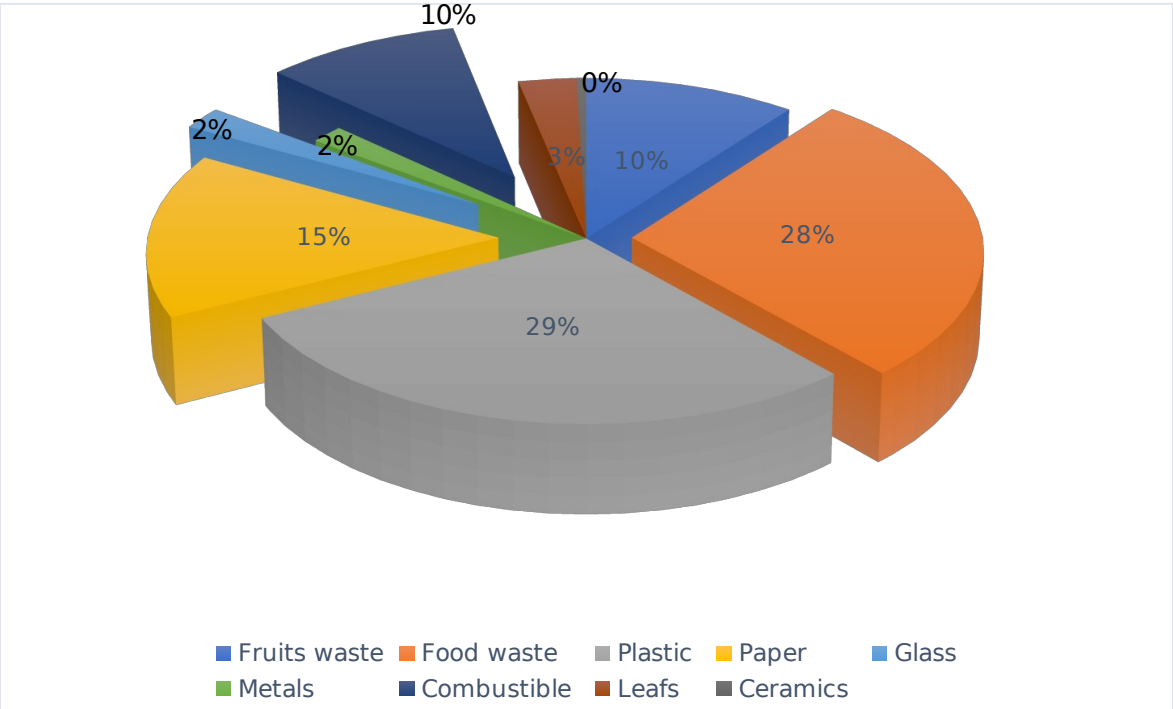
Differences in mean waste types generated for all the strata, Ugbowo campus University of Benin is statistically significant at p>0.05, d = 0.018

Source : Data Processed

Although it is illustrated in table 1. that plastic waste was the most waste generated at 2953.5kg, a combination of fruit waste (1058.4kg) with food waste (2823.5kg) in the real sense makes food waste the most generated stream of waste (3,881.9Kg). On the other hand, the least waste type was ceramic at 47.5kg. Leaves recorded 271.1kg.

It was illustrated as Plastic waste 29%, fruit 10% and left 3% in figure 10. Food waste was 28% and paper waste 15% (fig2).

Figure 2. Percentage Distribution Of Mean Waste Types Generated For All The Strata, Ugbowo Campus University Of Benin



Source : Data Processed

This study established that, on average, about 10,144.4kg of municipal solid waste is generated in the University of Benin Ugbowo campus every month. Based on this, the study area's per capital waste generation rate is 0.33Kg/cap/day. It collaborates with Egun's (2012) findings, who recorded the waste generation rate for Delta State at 0.3kg/cap/day and Babalola *et al*. (2010), who also recorded a similar result of 0.32kg/cap/day for Damaturu in Yobe State.

Food residues were the most abundant (38% food and fruit), followed by plastic 29% and paper 15%. It is in line with many previous research works, one of which is Seshie *et al.* (2020) that recorded the same trend of the highest food waste than plastic and

followed by a paper in a municipal solid waste study in Ghana. Mohamad *et al.* (2020) also reported a similar trend in waste composition. The abundance of food waste confirms the preferred consumption of whole fresh meals as the feeding habit on the campus.

Table 2. focuses on the easily biodegradable food, fruit and leaves(lignin) waste and the percentage generation for all three strata.

Table 2: Composition of OFMSW

Physical Composition of waste	**Commercial Area**		**Admin/ Lecture Area**		**Residential Quarters**		**Total**	
OFMSW	**Weight (kg)**	**%**	**Weight (kg)**	**%**	**Weight (kg)**	**%**	**Weight (kg)**	**%**
Fruit	275.5		58.5		724.4		1058.4	
Food	805.9		211.1		1806.5		2823.5	
leaves	200.9		70.2		0.00		271.1	
	1282.3	**52**	**339.8**	**15**	**2530.9**	**46**	**4153.0**	**41**

The table above illustrates that 52% of the waste was easily biodegradable in the commercial strata while the other 48% was either not easily biodegradable or nonbiodegradable, e.g., metals and plastics. The administrative and lecture hall region had a low generation of biodegradables (15%) which is in line with previous studies by Igbinomwanhia (2011), revealing biodegradable waste 14.56% in the administrative block of the University of Benin. On the other hand, 46% of the total waste generated

in the resident quarters during the study period was biodegradable, and food waste was the highest generated in the quarters (1806.5Kg).

The organic fraction of municipal solid waste is a biomass resource. The waste generated from Ugbowo Campus, University of Benin, has a mean biomass content of 115.9 kg/day (food waste, fruit waste, and leaf waste); 41% of the total waste can serve as feedstock for anaerobic digestion to produce biogas. According to World Bank (1999), generally, all low and middle-income countries have a high percentage of organic matter in the urban waste stream ranging from 40 to 85% of the total waste. Food waste is a viable resource for biogas production due to its high volatile solids (VS) content and high biodegradability (Zhang *et al.*, 2007; Igoni *et al.*, 2008). Volatile solid is the digestible portion of organic waste that ferments to produce biogas. From the total value of biodegradables in table 2, 0.197Kg of food waste is generated at the University of Benin per person each day. With an estimated population of about 52,000 (theeagleonline.com.ng, 2020), the University of Benin generates about 10.244tonnes of OFMSW daily. It will result in a TS of 2,780.22tonnes and VS of 2,638.43tonnes per day, considering 27.14% TS and 94.90% VS. Also, considering methane yield values of 367m3 /TVs, a total of 968.30m3 biogas is expected to be generated from the OFMSW of the University of Benin sub-metropolis per day.

This observation also collaborates with Akhator *et al.*'s (2016) findings that there is a high percentage of putrescible waste in domestic waste in the Benin metropolis. The study found that Food waste accounted for about 78.49% of the generated solid waste representing 0.281kg per person per day and a total daily food waste generation of 305.075tonnes. Based on this value for food waste, the obtainable biogas was estimated to be 28,836.91m^3 of biogas in the Benin metropolis per day.

CONCLUSION

At the time of this study, no systematic or integrated or circular solid waste management practices were followed except a collection of solid waste from central dumps or houses and transferring to be dumped at far-off places. It is simply moving the waste to larger dumpsites.

This study revealed that, about 10,144.4kg of municipal solid waste is generated in the University of Benin Ugbowo campus monthly. A waste generation of 0.33Kg/cap/day was established. Characterization and quantification of solid waste play a significant role in estimating material recovery potential and determining generation, treatment methods, and final disposal sources. This study illustrates that of the total waste generated, 41% is easily compostable and or biodegradable under controlled conditions to produce biogas that can either be utilized directly for cooking in commercial eateries or upgraded for electric power generation. The other 59% is either recyclable or easily combustible to generate energy.

Considering the characteristics of waste generated in the University of Benin, Ugbowo campus, a systematic blend of management options in the waste management, e.g., biogas technology and waste recycling technologies, would be more suitable than the unsustainable collection and final dumping system that is presently practiced. Furthermore, besides the biogas and generated renewable energy, the digestate can serve as ad biofertilizer, which can be used to cultivate crops.

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